

What Is Claimed Is:

1. A method of protecting a carbon fiber or carbon-carbon (C-C) composite component against high temperature oxidation, said method comprising the steps of:

5 applying a coating of fluidized borophosphate glass precursor over the component by immersing the C-C component in a bath containing glass precursor components including 25-50 weight-% phosphoric acid, 1-10 weight-% manganese phosphate, 2-20 weight-% potassium hydroxide, 1-10 weight-% boron nitride, 0-30 weight-% boron carbide, and 20-60 weight-%
10 water;

gradually heating the precursor-coated component to a temperature range at which glass transition temperature of the glass will be thermally matched to the oxidation temperature range of the carbon in the C-C component;

15 continuing to heat the glass-coated component to facilitate desired chemical reactions in the glass and glass precursor, as well as stress reduction; and

gradually cooling the glass-coated component to envelop said component in a solid glass coating.

20 2. The method of claim 1, wherein said component is configured as an aircraft landing system brake disc.

3. The method of claim 1, wherein said component is protected against oxidation at a temperature of about 1600°F.

4. The method of claim 1, comprising the steps of:
25 preparing a liquid precursor including 25-50 weight-% phosphoric acid, 1-10 weight-% manganese phosphate, 2-20 weight-% potassium hydroxide, 1-10 weight-% boron nitride, 0-30 weight-% boron carbide, and 20-60 weight-% water;

30 maintaining the precursor at a temperature in the range of between about 20-90°C;

applying a coating of the liquid precursor to an outer surface of the component; and

annealing the coated component at a temperature in the range of about 250-650°C,

5 thereby creating a solid glass protective coating of about 1-10 mils thickness around the component for protecting the component from oxidizing species.

5. An article comprising:

10 a component, made of carbon fiber or carbon-carbon (C-C) composite having a thickness of about 0.5 to 1.5 inches, annealed at a temperature in the range of about 2200-2600°C; and

 a glass coating of about 1-10 mil, made with a mixture containing 20-60 weight-% water, 25-50 weight-% phosphoric acid, 2-20 weight-% alkali metal hydroxide, 1-10 weight-% manganese phosphate, 0-10 weight-% boron
15 nitride, 0-13 weight-% elemental boron, and 2-50 weight-% boron carbide, wherein said glass coating covers and protects said component against oxidizing species when the article is subjected to temperatures of up to about 900°C.

6. The article of claim 5, wherein said component is configured as
20 an aircraft landing system brake disc.

7. A method of protecting a thin-gauge carbon fiber or carbon-carbon (C-C) composite component against oxidation, the method comprising the steps of:

25 applying a coating of fluidized borophosphate glass precursor over the component by immersing the C-C component in a bath containing glass precursor components including at least 2 weight-% boron carbide and no more than 13 weight-% elemental boron;

 gradually heating the precursor-coated component to a temperature range at which glass transition temperature of the glass will be thermally

matched to the oxidation temperature range of the carbon in the C-C component;

continuing to heat the glass-coated component to facilitate desired chemical reactions in the glass and glass precursor, as well as stress

5 reduction; and

gradually cooling the glass-coated component to envelop the C-C component in a solid glass coating.

8. The method of claim 7, wherein said bath contains glass precursor components including at least 10 weight-% boron carbide and no
10 more than 5 weight-% elemental boron.

9. The method of claim 7, wherein the glass precursor components comprise 20-60 weight-% water, 25-50 weight-% phosphoric acid, 2-20 weight-% alkali metal hydroxide, 1-10 weight-% manganese phosphate, 0-10 weight-% boron nitride, 0-13 weight-% elemental boron, and 2-50 weight-%
15 boron carbide.

10. The method of claim 9, wherein the glass precursor components comprise 20-60 weight-% water, 25-50 weight-% phosphoric acid, 2-20 weight-% alkali metal hydroxide, 1-10 weight-% manganese phosphate, 1-10 weight-% boron nitride, 0-5 weight-% elemental boron, and 10-28 weight-%
20 boron carbide.

11. The method of claim 7, wherein the coating of fluidized glass precursor is applied by rotating either the C-C component or the bath relative to one another when the component is immersed in the fluidized glass precursor to completely and uniformly cover the component with the fluidized
25 glass precursor.

12. The method of claim 7, wherein the component is immersed in the precursor bath for more than one minute.

13. The method of claim 7, wherein the step of heating the glass precursor coated component is conducted at a rate of about 1-2°C per minute

to a temperature of between about 250-350°C and wherein the temperature is then maintained at about 250-350°C for a period of between 1-10 hours.

14. The method of claim 7, wherein the step of continuing to heat
5 the coated component is conducted at a temperature of between about 550-650°C for a period of between 1-10 hours.

15. A method of protecting a thin-gauge carbon fiber or carbon-carbon (C-C) composite component against oxidation, the method comprising the steps of:

- 10 preparing a liquid precursor including phosphoric acid, manganese phosphate, potassium hydroxide, boron nitride, boron carbide, and water;
maintaining the precursor at a temperature in the range of between about 20-90°C;
applying a coating of the liquid precursor to an outer surface of the
15 component; and
annealing the coated component at a temperature in the range of about 250-650°C,
thereby creating a solid glass protective coating of about 1-10 mils thickness around the component for protecting the component from oxidizing
20 species.

16. The method of claim 15, wherein the liquid precursor components comprise 25-50 weight-% phosphoric acid, 1-10 weight-% manganese phosphate, 2-20 weight-% potassium hydroxide, 0-10 weight-% boron nitride, 2-28 weight-% boron carbide, and 20-60 weight-% water.

- 25 17. The method of claim 16, wherein the liquid precursor components comprise 20-60 weight-% water, 25-50 weight-% phosphoric acid, 2-20 weight-% alkali metal hydroxide, 1-10 weight-% manganese phosphate, 1-10 weight-% boron nitride, 0-5 weight-% elemental boron, and 10-28 weight-% boron carbide.

18. The method of claim 15, comprising the step of gradually heating the precursor-coated component at a rate of 1-2°C per minute until reaching a temperature in the range of about 250-350°C and maintaining this temperature for between 1-10 hours to further anneal the coated component.

5 19. The method of claim 15, comprising the step of gradually heating the precursor-coated component from a temperature in the range of about 250-350°C to a temperature in the range of about 550-650°C and maintaining this temperature for between 1-10 hours to further anneal the coated component.

10 20. The method of claim 15, wherein the C-C component has a thickness of about 3-30 mils.

21. The method of claim 15, wherein said thin-gauge carbon fiber or carbon-carbon composite component is a heat exchanger core.

22. A method of forming an oxidation protected carbon-carbon (C-
15 C) composite component, the method comprising:
forming thin-gauge two-dimensional woven fabric panels;
rigidizing the panels with a small percentage of carbon-containing resin;
carbonizing the panels at a temperature in the range of about 800-
20 1000°C;
densifying by chemical vapor deposition;
annealing the component at a temperature in the range of about 2200-2600°C; and
applying a coating of fluidized glass precursor over the component, by
25 immersing the C-C component in a bath containing glass precursor components including at least 2 weight-% boron carbide and no more than 13 weight-% elemental boron, to cover the C-C component, thereby protecting the component against oxidizing species.

23. The method of claim 22, wherein said bath contains glass precursor components including at least 10 weight-% boron carbide and no more than 5 weight-% elemental boron.

24. An article comprising:

5 a thin-gauge component, made of carbon fiber or carbon-carbon (C-C) composite having a thickness of about 3-30 mils, annealed at a temperature in the range of about 2200-2600°C; and

a glass coating of about 1-10 mil, made with a mixture containing 20-60 weight-% water, 25-50 weight-% phosphoric acid, 2-20 weight-% alkali
10 metal hydroxide, 1-10 weight-% manganese phosphate, 0-10 weight-% boron nitride, 0-13 weight-% elemental boron, and 2-50 weight-% boron carbide, wherein said glass coating covers and protects said component against oxidizing species when the article is subjected to temperatures of up to 800°C.

15 25. The article of claim 24, wherein the component is of complex shape.

26. The article of claim 24, wherein the glass coating is annealed to the component at a temperature in the range of about 250-650°C.

27. The article of claim 24, wherein the glass precursor components
20 comprise 20-60 weight-% water, 25-50 weight-% phosphoric acid, 2-20 weight-% alkali metal hydroxide, 1-10 weight-% manganese phosphate, 1-10 weight-% boron nitride, 0-5 weight-% elemental boron, and 10-28 weight-% boron carbide.